

THE MICROBIAL FOOD WEB: COMPARATIVE STUDY UNDER FIRST-YEAR ICE AT LOW AND HIGH LATITUDES IN THE NORTHERN HEMISPHERE

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Abstract: In spring of 1992, the microbial compartment at the base of first-year ice in Saroma Ko lagoon (northern Hokkaido, Japan) and Resolute Passage (Canadian High Arctic) was investigated. Chlorophyll concentration, bacterial concentration and microheterotrophy were compared at both sites. Bacterial activity and productivity were insufficient in both sites to satisfy the demand of microheterotrophs. Accordingly, a shift probably occurred in the grazing behavior of heterotrophic nanoprotozoans as the ice-algal bloom took place.

1. Introduction

The trophic structure of aquatic food webs affects the flow of energy that reaches top trophic levels. It is generally assumed that a greater number of trophic steps leads to more energy dissipation from respiration and excretion resulting in less energy being transferred to higher trophic levels (POMEROY, 1984). A substantial fraction of the carbon fixed by the primary producers is excreted as dissolved organic carbon (DOC) (LARSSON and HAGSTROM, 1982). The bacterio-plankton uses this carbon source and then makes it available for heterotrophic nanoprotozoans (WILLIAMS, 1981; AZAM *et al.*, 1983).

Heterotrophic nanoprotozoans are currently thought to be the major consumers of bacterial production in many aquatic ecosystems (SHERR and SHERR, 1984; SANDERS *et al.*, 1989). These organisms play a crucial role in the regulation of microbial pathways of carbon in marine food webs and can determine the fate of the bacterial production (PACE *et al.*, 1990). The role of the microbial loop in Antarctic waters is especially important during the dark winter, when primary production is absent and all secondary production is presumably supported by a

detritus-based food web. This role is diminished during spring, when primary production greatly exceeds bacterial production (AZAM *et al.*, 1991).

In the spring of 1992, a team of Japanese and Canadian scientists studied the primary production and the microbial compartment at the base of first-year ice in Saroma Ko lagoon (northern Hokkaido, Japan) and Resolute Passage (Canadian High Arctic). The objective of the program was to contribute to an understanding of the carbon exchanges between the atmosphere and ocean under the first year ice at low and high latitudes in the arctic with an emphasis on the role of the marine food web in these processes. This paper briefly describes the temporal dynamic of the chlorophyll and the bacterial concentration under the first year ice at the two sites.

2. Sampling Sites

The study at Saroma Ko lagoon involved samples taken from February 25 to March 16 1992, at two different sites: a natural site, covered with the undisturbed snow thickness and an open site where the snow was cleared. For Resolute, the ice camp was located approximately 2 km offshore in the Resolute passage, Northwest Territories, Canada. The water depth was about 125 m and the area was entirely covered with first-year land-fast ice. The sampling period was from April 13 to May 22 1992, on two different sites: a thick site with approximately 25 cm of snow and a thin site with less than 7 cm of snow cover.

3. Results and Discussion

At Saroma Ko, the irradiance at the surface of the ice varied from $700 \mu\text{mol quanta m}^{-2} \text{s}^{-1}$ to about $1500 \mu\text{mol quanta m}^{-2} \text{s}^{-1}$ (Fig. 1A). During this period, a snow storm deposited around 40 cm of snow on the ice. This snow storm modified substantially the light intensity under the ice (Fig. 1B). At Resolute, the light

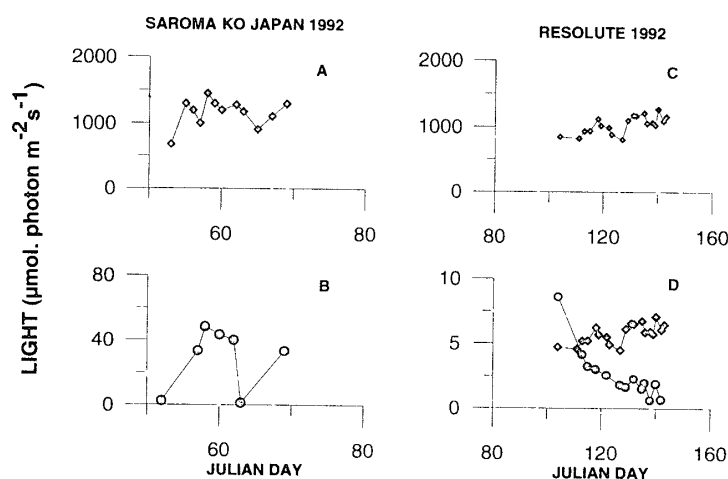


Fig. 1. Saroma light intensity (A) at the surface and (B) below the ice and at Resolute (C) at the surface of the ice and (D) under (○) and below (■) the chlorophyll layer.

intensity varied from about $800 \mu\text{mol quanta m}^{-2} \text{s}^{-1}$ to about $1250 \mu\text{mol quanta m}^{-2} \text{s}^{-1}$ with an increase from the beginning to the end of the sampling period (Fig. 1C). Under the ice, the light intensity decreased continuously from the beginning to the end of the sampling season (Fig. 1D). At Resolute, the light intensity measurements were also made after removing the chlorophyll layer. There was 10 times more light just above the chlorophyll layer than below. In order to calculate the light intensity reaching the algae, we applied a correcting factor to the light intensity reaching the surface of the ice and plotted the real light reaching the ice algae during the season. These calculated measurements are shown in Fig. 1D, and they indicated that the decrease in the light intensity under the ice at Resolute probably reflected the light attenuation by chlorophyll.

At Saroma Ko, the natural site with a thick snow cover showed an increase of the chlorophyll *a* concentration at the beginning of the sampling season during the first four days (Fig. 2A) and the values reached the maximum concentration of about 40 mg m^{-2} and then the chlorophyll *a* concentration decreased slowly and reached a value of about 20 mg m^{-2} at the end of sampling. At the open site, the chlorophyll concentration decreased progressively from 20 mg m^{-2} to less than 10 mg m^{-2} and the values were lower than at the natural site (Fig. 2A). In the Resolute Passage (Fig. 2B), the chlorophyll concentration at the bottom of the ice under a thin snow cover showed a first phase of low values ($40\text{--}50 \text{ mg m}^{-2}$) during the first days followed by a drastic increase of the chlorophyll concentration by the middle of the sampling period. The maximum values were about 150 mg m^{-2} . The thick

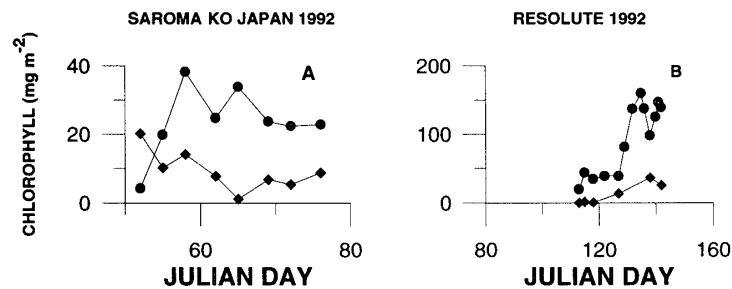


Fig. 2. Chlorophyll concentration at (A) Saroma under the natural (●) and the open site (■) and (B) Resolute under the thin (●) and the thick (■) snow cover.

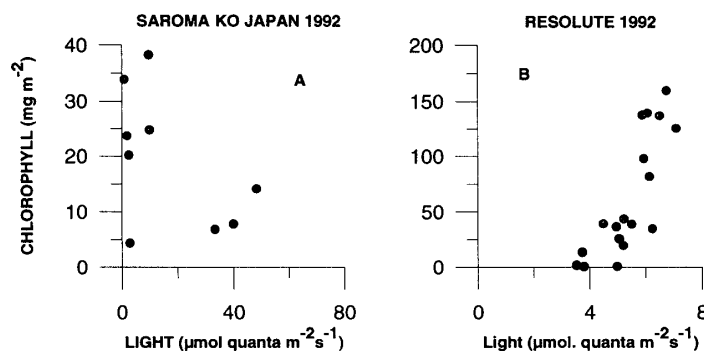


Fig. 3. Relationship between light intensity under the ice and the chlorophyll concentration at (A) Saroma Ko and (B) Resolute.

snow cover site showed a small increase and values never exceeded 40 mg m^{-2} .

The light intensity seems the key factor in the control of the chlorophyll concentration under the ice. At Saroma Ko, there was an inverse correlation between the light intensity and the chlorophyll concentration at the ice water interface under the two sites (Fig. 3A). However, at Resolute, the relationship between the light intensity just above the chlorophyll layer and the chlorophyll concentration showed a direct correlation (Fig. 3B). As already showed for the Hudson Bay, the light required for the growth of ice algae varied between 7.5 to $35 \mu\text{mol quanta m}^{-2} \text{ s}^{-1}$ (GOSSELIN *et al.*, 1985). Outside these light limits, the growth is inhibited. The difference in the ice thickness and the snow cover between the two locations suggested that the two sites represented the lower and the upper limit of the light range where the ice algae can growth.

At Saroma Ko, the bacteria showed no difference between the natural and the open sites (Fig. 4). In the ice, the bacterial concentration increased to reach a plateau followed by a decrease suggesting that there was a bacterial activity (Fig. 4A). At the ice water interface (Fig. 4B), we observed a decrease in the concentration of bacteria. This decrease of the bacterial concentration in the frazil could be the result of the grazing activity of bacteriovorous nanoflagellates or the sinking of bacteria in the water column (Fig. 4C). In Resolute (Fig. 4D, E, F), there was more bacteria, in the frazil under the thin snow cover than under the thick (Fig. 4E). This probably reflects the difference between sites in the algal biomass concentration.

Table 1 shows the contribution of each constituent of the microbial community

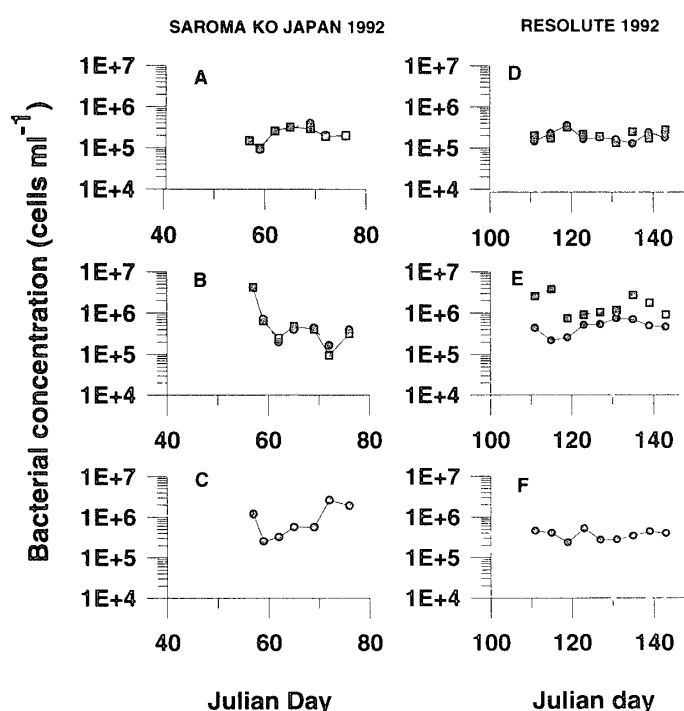


Fig. 4. Bacterial concentration at Saroma (A, B, C) and Resolute (D, E, F) for the ice, the ice/water interface and the water column respectively: natural (○) and open (■) sites.

Table 1. Saroma Ko Japan 1992: Microheterotroph standing stock integrated carbon biomass from 0 to 30 cm for bottom ice of natural and open site.

	Mean biomass	(C.V. %)
	Natural site	Open site
Free living bacteria (mg C m^{-2})	0.8 (60)	1.2 (97)
Heterotrophic flagellates (mg C m^{-2})	65.3 (123)	36.1 (63)
Phagotrophic ciliates (mg C m^{-2})	2.3 (103)	1.3 (85)
Total	68.4	38.6

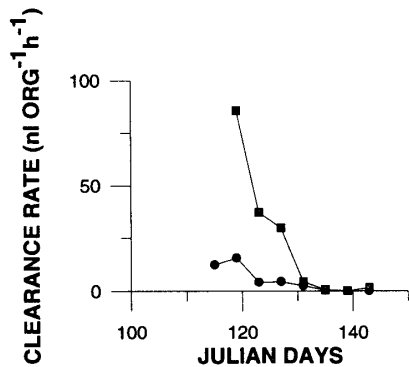


Fig. 5. Resolute clearance rates under thick (■) and thin (●) snow cover.

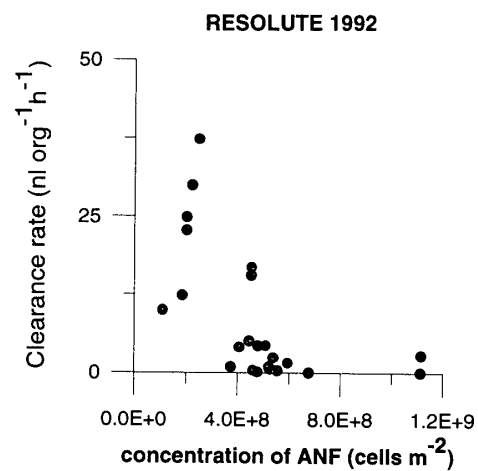


Fig. 6. Nanoprotezoans clearance rates in relation to autotrophic nanoflagellates (ANF).

in term of carbon for Saroma. Flagellates dominated the community at the bottom of the ice contrary to the number of bacteria where there is no difference between the two sites, the biomass in term of carbon showed a marked difference suggesting the occurrence of larger cells under the open site. These suggest that the grazing impact on bacteria was likely more pronounced in the natural site, because of the absence of larger bacteria which are known to be preferentially removed by micrograzers.

At Resolute, the grazing activity on bacteria measured with the Fluorescent Labelled Bacteria (FLB) method decreases to near zero as the season progresses (Fig. 5). The clearance rate under the thick snow cover started at higher value ($86 \text{ nl org}^{-1} \text{ h}^{-1}$) than for the thin snow cover ($12 \text{ nl org}^{-1} \text{ h}^{-1}$).

The clearance rate on bacteria seems greatly influenced by the food concentration at the ice water interface. It seems that there is a shift in the protozoan diet even if the bacteria concentration is still high. The clearance rates showed an inverse relationship with the abundance of autotrophic nanoflagellates (Fig. 6) (see LAURION *et al.* (in press) Mar. Ecol. Prog. Ser. for more details).

The results of Saroma and Resolute suggest that (1) ice algae has a small range of light requirements and (2) protozooplankton could have an important grazing impact on bacteria in the first year ice at low algal biomass but they can shift to other source of carbon to maintain their growth.

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